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# Overall review of wind power development in Inner Mongolia: Status quo, barriers and solutions

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ABSTRACT

Inner Mongolia is one of the main wind power bases of China accounting for nearly 30% wind capacity of the country. But its wind power available hours are lower than the national average, and issues of integration and consumption of wind energy become a problem, causing for transmission line construction or grid security consideration. Wind power development in Inner Mongolia including status quo, barriers and solutions are researched, and this paper analyzed the development issues of Inner Mongolia from aspects of technology and mechanism, and put forward orderly development solutions for Inner Mongolia wind power in corresponding.



**Contents**



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## 1. Introduction

Wind power is renewable energy that produces more energy after large hydropower [1]. China is one of the world leaders in wind power installed [2]. Among them, Inner Mongolia accounts for $1.46 \times 10^6$ MW installed capacity for exploitation [3]. Furthermore, wind energy resources that can be exploited in technology in Inner Mongolia account for about 50% of the total in China [4]. At the same time, two of the eight planning and constructing inland 10-million-kilowatt wind power bases are located in Inner Mongolia. But by the end of 2011, China's wind power installed capacity was only 4.27% of the total installed capacity, while wind power production was 1.54% of all power production [5]. Inner Mongolia had 28.21% wind capacity of China, but its wind power generation just accounts for 27.42% of the national wind generation and 0.46% of all generation in China [6]. In 2011, average operation hours of wind power and thermal power of Inner Mongolia power grid were 1829 and 4923, respectively, while the national average available hours of wind power were 1920 this year [7]. Hence, the matter of wind power integration in Inner Mongolia need to be solved urgently and it will affect wind energy resources exploitation and wind power industry development in China to a great extent if not be solved [8].

Inner Mongolia is an important wind power land in China, and can represent the difficulties in the process of the development in China's wind power industry mostly, so this paper will study barriers of Inner Mongolia wind power development and give some suggestions.

## 2. Status quo analysis of Inner Mongolia wind power development

### 2.1. Installed capacity

Inner Mongolia is located in north China, stretching across the northeast China, north China and southwest China. The south of

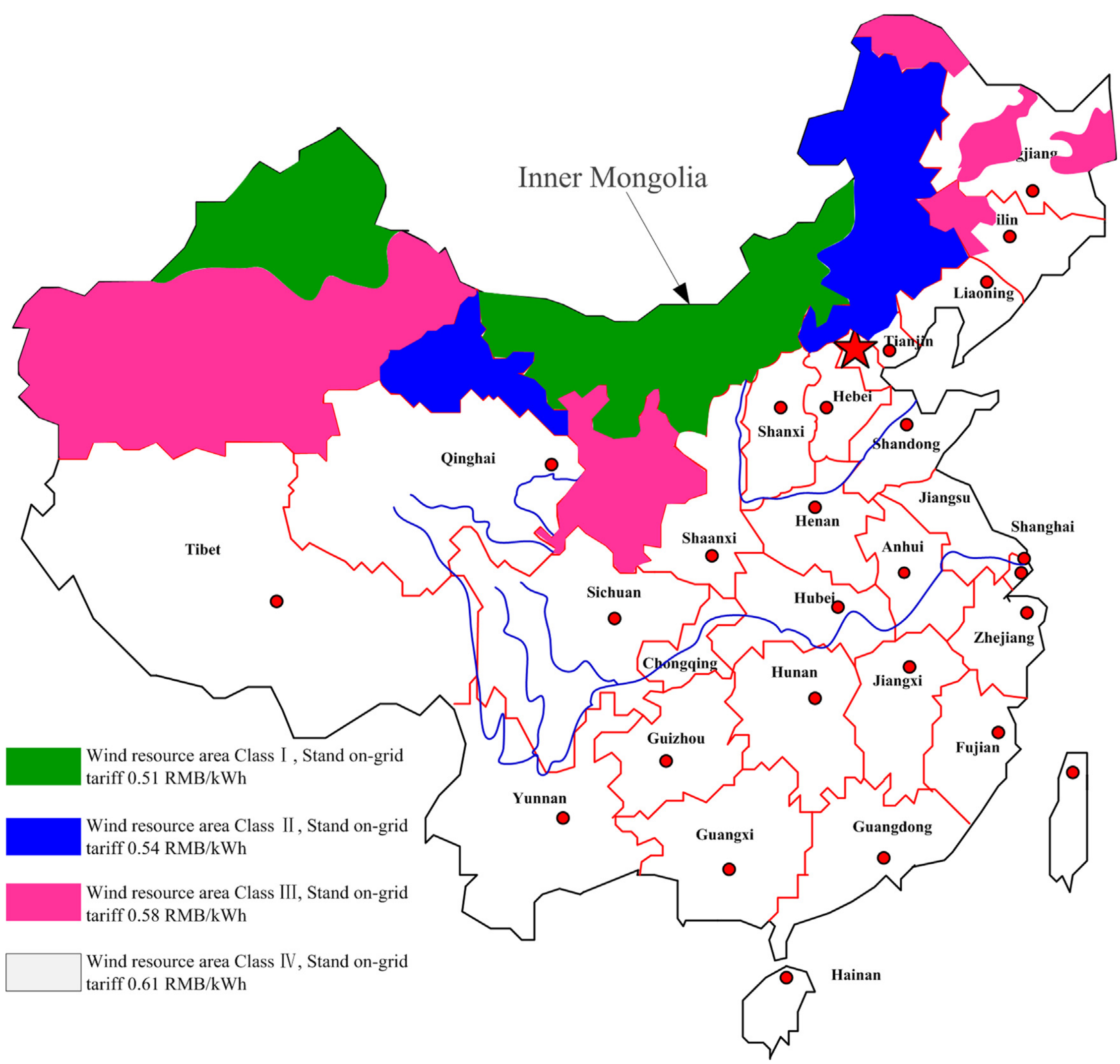


**Fig. 1.** Wind energy resource map in China.

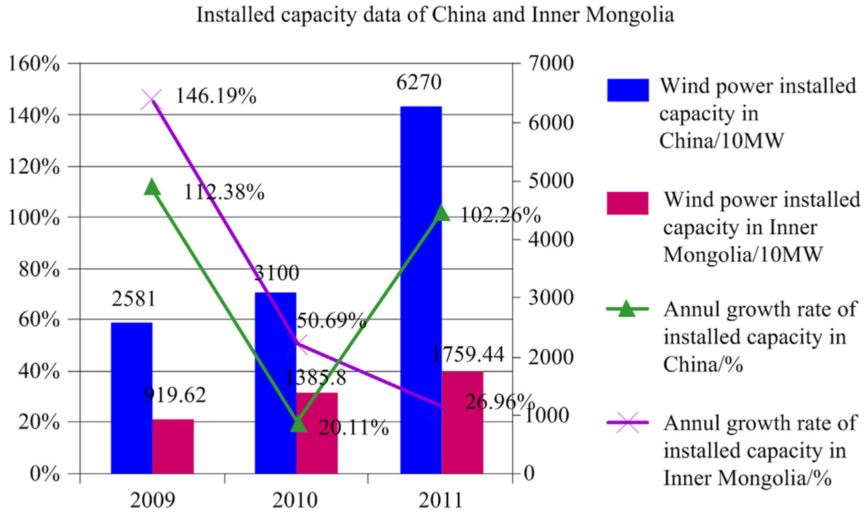


**Fig. 2.** Installed capacity data of China and Inner Mongolia [11–13].

Inner Mongolia is close to Beijing and Tianjin while the north is adjacent to Mongolia and Russian. In June 2012, wind power integration installed capacity reached at 52,580 MW [9] exceeding that in United States and becoming first in world. Wind power resources distribution in China is shown in Fig. 1 [10]. From the chart can be found that the high quality wind power resources are most distributed in Inner Mongolia region. From 2009 to 2011, wind power installed capacity in China were respectively 25,810 MW, 31,000 MW and 62,700 MW, and annual rate of growth respectively were 112.38%、 20.11% and 102.26%. Meanwhile, wind power installed capacity in Inner Mongolia autonomous region were 9196.2 MW, 13,858.0 MW and 17,594.4 MW, and corresponding annual rate of growth were 146.19% in 2009, 50.69% in 2010 and 26.96% in 2011, as shown in Fig. 2 [11–13].

China's newly increased wind power installed capacity in 2011 were 18 GW, accounting for 40% of the global total increment, and the Inner Mongolia added wind capacity of 3736.4 MW [13]. By the end of 2011, Inner Mongolia is still ranking first in China with accumulated wind power installed capacity of 17,594.4 MW, while Hebei province for 6969.5 MW ranking second and Gansu province for 5409.2 MW ranking third on gross wind capacity in China. Top 10 provinces were shown in Table 1·[14].

### 2.2. Production

China wind power generation from 2009 to 2011 is respectively 27.6 billion kW h, 50.1 billion kW h and 80 billion kW h, and corresponding annual rate of growth is 115.76% in 2009, 81.41% in 2010 and 59.68% in 2011, accounting for 0.76%, 1.21% and 1.74% of the national total generation production. In contrast, Inner Mongolia's wind power generation in year 2009, 2010 and 2011 is 9.81 billion kW h, 19.924 billion kW h and 25.9 billion kW h while corresponding year-on-year growth rate is 162.3%, 103.1% and 29.7%. The thermal power generation growth rate in 2011 is 17.7% [15]. Relevant data can be seen in Fig. 3.

In 2009, power production in Inner Mongolia was 223.985 billion kW h and wind power accounted for 4.38%; production in 2010 was 248.388 billion kW h and production rate of wind power was 8.02%; In the year 2011, total production was 297.285 billion kW h and wind power accounting for 24% of total installed capacity in Inner Mongolia only accounted 8.71% of the whole power production (By the end of 2011, installed capacity in Inner Mongolia was 736,336 MW) [15].

In general speaking, wind power industry in Inner Mongolia have a rapid development speed and is on the domestic leading level from the view of installed capacity and power generation. But annual available hours in Inner Mongolia is lower than the national average level [7], so Inner Mongolia wind power with characteristics of large scale and intensification faces some

**Table 1**
Newly and cumulatively installed wind power capacity of different provinces in China by late 2011 (MW).

| Number | Province | Installed capacity by 2010 | Newly installed capacity in 2011 | Cumulatively installed capacity by 2011 | Proportion of total installed capacity (%, 2011) |
|---|---|---|---|---|---|
| 1 | Inner Mongolia | 13,858.0 | 3,736.4 | 17,594.4 | 28.21 |
| 2 | Hebei | 4,794.0 | 2,175.5 | 6,969.5 | 11.18 |
| 3 | Gansu | 4,944.0 | 465.2 | 5,409.2 | 8.67 |
| 4 | Liaoning | 4,066.9 | 1,182.5 | 5,249.4 | 8.42 |
| 5 | Shandong | 2,637.8 | 1,924.5 | 4,562.3 | 7.32 |
| 6 | Jilin | 2,940.9 | 622.5 | 3,563.4 | 5.71 |
| 7 | Heilongjiang | 2,370.1 | 1,075.8 | 3,445.9 | 5.53 |
| 8 | Ningxia | 1,182.7 | 1,703.5 | 2,886.2 | 4.63 |
| 9 | Sinkiang | 1,363.6 | 952.5 | 2,316.1 | 3.71 |
| 10 | Jiangsu | 1,595.3 | 372.3 | 1,967.6 | 3.16 |
| 11 | Shanxi | 947.5 | 933.6 | 1,881.1 | 3.02 |
| 12 | GuangDong | 888.8 | 413.6 | 1,302.4 | 2.09 |
| 13 | FuJian | 833.7 | 192.0 | 1,025.7 | 1.64 |
| 14 | YunNan | 430.5 | 501.8 | 932.3 | 1.49 |
| 15 | ShaanXi | 177.0 | 320.5 | 497.5 | 0.80 |
| 16 | ZheJiang | 298.2 | 69.0 | 367.2 | 0.59 |
| 17 | ShangHai | 269.4 | 48.6 | 318.0 | 0.51 |
| 18 | HeNan | 121.0 | 179.0 | 300.0 | 0.48 |
| 19 | AnHui | 148.5 | 148.5 | 297.0 | 0.48 |
| 20 | HaiNan | 256.7 | – | 256.7 | 0.41 |
| 21 | TianJin | 102.5 | 141.0 | 243.5 | 0.39 |
| 22 | GuiZhou | 42.0 | 153.1 | 195.1 | 0.31 |
| 23 | HuNan | 97.3 | 88.0 | 185.3 | 0.30 |
| 24 | BeiJing | 152.5 | 2.5 | 155.0 | 0.25 |
| 25 | JiangXi | 84.0 | 49.5 | 133.5 | 0.21 |
| 26 | HuBei | 69.8 | 30.7 | 100.4 | 0.16 |
| 27 | GuangXi | 2.5 | 76.5 | 79.0 | 0.13 |
| 28 | QingHai | 11.0 | 56.5 | 67.5 | 0.11 |
| 29 | ChongQing | 46.8 | – | 46.8 | 0.08 |
| 30 | SiChuan | 0.0 | 16.0 | 16.0 | 0.03 |
| 31 | HongKong | 0.8 | – | 0.8 | 0.00 |
| In summary | | 44,733.3 | 17,630.9 | 62,364.2 | 100.00 |
| 32 | Taiwan | 519 | 45 | 564 | |
| In total | 45,252.3 | 17,675.9 | 62,928.2 | | |

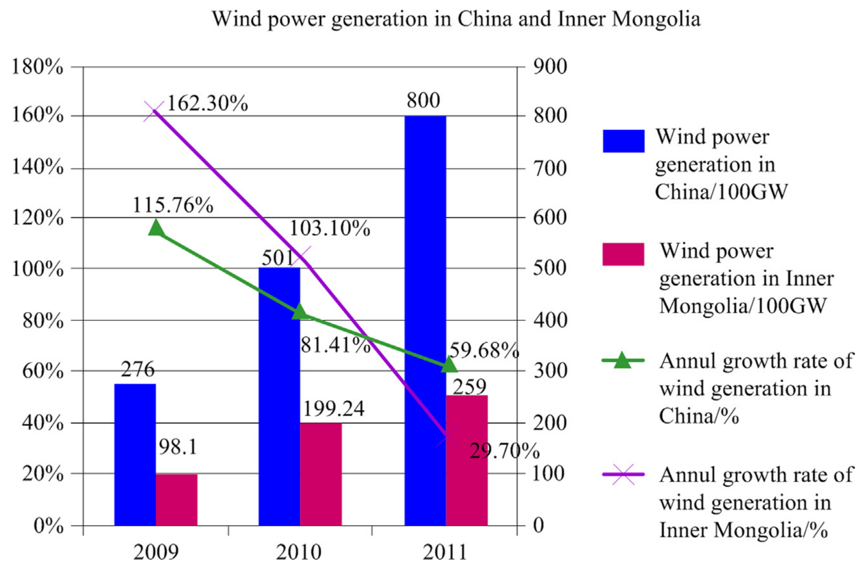


**Fig. 3.** Production data of China and Inner Mongolia [15].

pressing problems such as lower wind power unit available hours and integration rate.

## 3. Barriers of wind power development in Inner Mongolia

According to the status quo analysis of Inner Mongolia wind power development above, now the prominent matter of wind power development in Inner Mongolia are wind power unit–operation hours and integration rate is on a low side. The reasonable available hours of wind power are 2600–3000 every year [16,17], but from the data of 2010, annual available hours of wind power in MengDong reached 2221 h and MengXi were less than 2100 which means abandon hours were over 500 and losing generation were more than 3 billion kW h; And in the all region the average available hours of wind power unit were 1943 [18]. In the year 2011, wind power unit average available hours of MengXi decreased to 1829 and MengDong 1863. Accumulated average operation time of all power equipment in Inner Mongolia in 2011 were 4448 h including hydroelectric 2233 h, thermal power 5102 h [19].

In the first half of 2012, the Inner Mongolia wind power generation was $1.39 \times 10^7$ MW, accounting for 11.4% of the total wind consumption in China. Among them, the MengXi grid $8.8 \times 10^6$ MW with year-on-year rate increased 18.2% and generating set average available hours in 6 months up to 1000 h which was 102 h less than last year [20]. The MengDong grid generate electricity $5.1 \times 10^6$ MW with a 13.8% year-on-year rate increased, and generating set average available hours was 862 which was 119 h decreased than the first half of 2011. At present, 94 wind power stations that have been in operation in Inner Mongolia but only 44 of them can operate over 2000 h. That is to say, more than half stations are defective and there are 13 stations with a running time less than 1000 h [20].

From a comprehensive perspective, the reasons to hard integration of wind power in Inner Mongolia region can be concluded into two parts. One is technology matter such as the ability of using electricity in local is insufficient; the construction of wind power is discordance with grid planning or load shortage of Power system, et al. The other problem is mechanism obstacle. For example, interest compensation mechanism about wind and thermal power have not been built and operation mode of power generation scheduling is incompatible with the require of wind power development. Specific analysis is shown as below.

### 3.1. Technical matter

#### 3.1.1. Uncoordinated wind power and transmission grid planning resulted in imperfect delivery channel construction

Wind power installed capacity exceeds the limitation of local grid digestion. According to the 12th Five-Year Plan of Wind Power Development and Accessing to Grid in Inner Mongolia, which is published in May 2011, integration of cumulative installed capacity of wind power will reach 33,000 MW which is consist of 20,000 MW in Mengxi and 13,000 MW in Mengdong. As to the 12th Five-Year Plan of Mengdong grid, installed capacity of supply power may reach 40,610 MW in 2015 and 73,720 MW in 2020, but maximum load in Mengdong just will be 10,440 MW in 2015 and 18,030 MW in 2020, so electricity production of wind power need to be transmitted and consumed in other regions [21]. In 2010, wind power that can be consumed in local region of Inner Mongolia approximately accounted for 7.4% of total installed capacity in Inner Mongolia. But from the government statistics about wind power construction and planning level of Inner Mongolia, wind capacity had reached over 10% of total capacity by the end of 2010 exceeding the limitation of local consumption [22].

The phenomenon of “49.5 MW” exists frequently, and construction of wind farm and grid is out of sync. Local government got examination and approval authority of small-scale wind power projects from May 2011. According to the rules, wind projects over 50 MW must be confirmed by national government and below 50 MW can be allowed by local government [23]. With active promotion of local government, some power generation enterprises take larger-scale wind power projects apart into many small-scale projects which have a capacity below 50 MW (most of them are 49.5 MW) to declaration, and once be approved it will cause a bad situation namely multi-wind farm connected to grid by stages and centralized wind power access to grid in parts of the area. The segmentation between power projects and grid projects lead to the phenomenon of mismatch between wind farm construction and power grid construction [24]. Often appear that wind power projects have been approval but the supporting transmission grid construction projects have not been planned opportunely. In addition, transmission grid construction cycle is

longer than wind power unit installation time also restricts development of wind power. Take KaiLu wind power base as an example whose installed capacity is over a thousand MW in TongLiao, KaiLu base got a permission by national energy bureau in 2008, and was planned to put into production Successively in 2009. However, the national energy bureau did not issue supporting permission of wind electricity transmission grid engineering until 2009 [25]. Uncoordinated wind power and transmission grid planning reduced consumption of wind power in Inner Mongolia and resulted in that constructed wind power base facing challenges of power delivery to other regions.

*3.1.2. Lacking wind power integration supporting power sources resulted in insufficient peak regulation*

Wind power has characteristics of random and intermittent but grid enterprise and power consumers require a stable power supply which needs flexible support power to stabilize the intermittent output of wind power and load shifting. However, Inner Mongolia is short of water resources and wind production regulation mainly rely on thermal power, proportion of flexible power such as pumped-hydro storage and gas-fired power plants is less than 2% [26]. Especially in winter, heating units account for a large proportion and these heating units basically lose the peak regulation ability. For example, according to statistics data in the end of 2008, the average vacancy installed capacity of peak regulation units in Inner Mongolia reached 1000 MW [27]. By the end of April 2012, thermal power installed capacity reached 31,072 MW among which heating units capacity accounting for 57.35% [28]; the high proportion of heating units caused insufficient load regulation ability in heating period and wind power production had to be abandoned for “giving way” to heating units. Meanwhile, substitutional relationship among integrating wind power and thermal power decides that enlarging digestion of wind power must occupy integration thermal power's power production.

In Inner Mongolia, Hohhot pumped storage power station is the first station which is constructed for wind power load regulation and will be finished in 2014. The 4300 MW-vertical single-stage reversible mixed flow units are supposed to be installed, which makes the total installed capacity 1200 MW. Designed annual output is 2 billion kW h [29]. Hohhot pumped storage power station is of low construction and operation cost and is capable of shaving peak, filling valley and fast tracking load variation. Therefore, it can undertake the task of peak regulation and valley filling, as well as emergency reserve, frequency modulation and phase modulation, which could increase dynamic profit of the system. If the 1200 MW installed capacity of Hohhot pumped storage power station acted as flexible power for wind load regulation and wind and water complementary can be realized, the grid digestion electricity generation will add 2000 MW wind power. At present, construction of pumped storage power station in Inner Mongolia has two challenges, the first is construction cycle is as long as

**Table 2**
Wind power transmission line route of Mengxi grid.

| Line number | Route | Wind power delivery capacity (MW) |
|---|---|---|
| ① | Fengquan–Wanquan–Shunyi and Hanhai–Guyuan–Pingancheng transmission line | 2000 |
| ② | Siziwang wind power centralized station—Togtoh–Hunyuan transmission line | 2400 |
| ③ | Xilingol wind power centralized station – Shangdu power plant – Chengde transmission line | 1200 |
| ④ | Chayouzhongqi wind power centralized station – Daihai power plant – Wanquan line | 1200 |
| ⑤ | Jiqing—North China (East China) $\pm 660$ kV DC transmission line | 4000 |
| ⑥ | Ninggeer – Southern Hebei province and Sanggendalai – Chengde line | 4000 |
| ⑦ | Ordos–South China $\pm 800$ kV DC transmission line | 8000 |

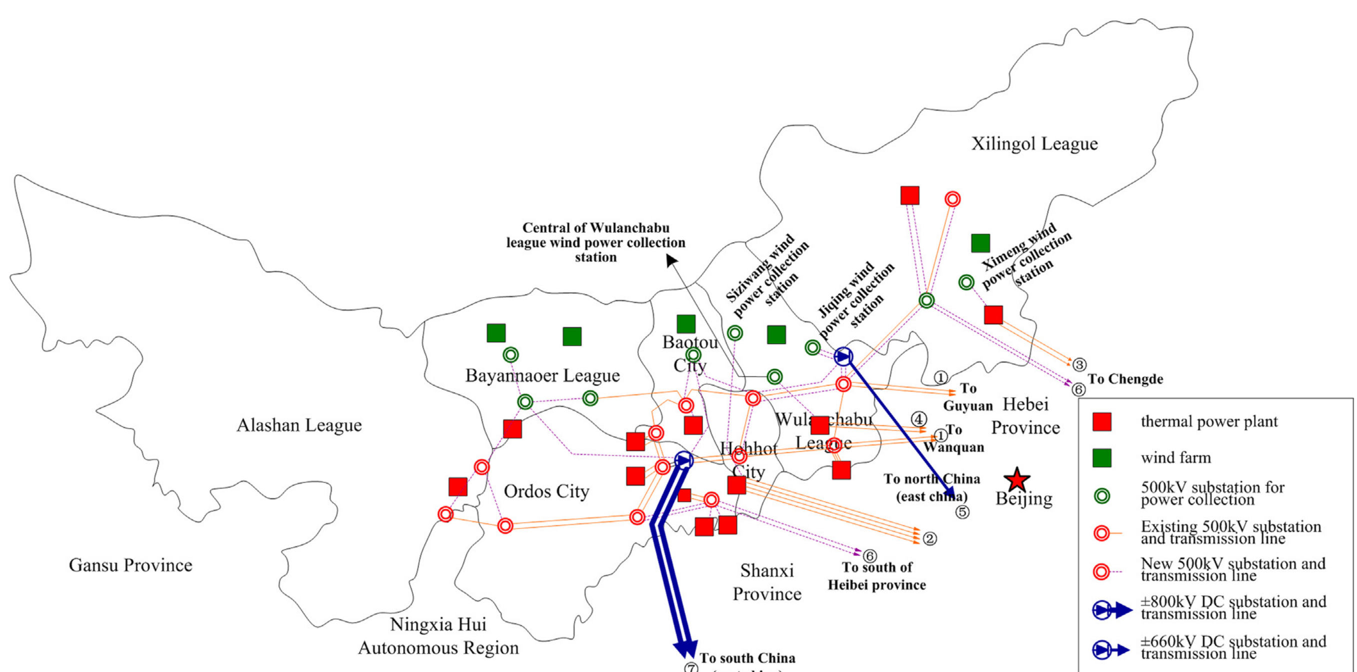


**Fig. 4.** Wind power transmission line route map of Mengxi grid.

4–5 years so pumped storage power station participate in wind power load regulation in large scale may be waiting until 2015; the second challenge is Chinese government has not formulated reasonable price policy to promote investment on pumped storage power.

The only gas-steam combined cycle unit using natural gas power generation in Inner Mongolia is located in Sulige gas field with annual electricity sales about $1.33\times10^6$ MW connected to grid in 2006 as an important load regulation power of Mengxi grid. However, restricted by investment cost and installed capacity scale, its ability of peak regulation is not enough relative to wind power with large capacity scale.

#### 3.1.3. Grid structure is weak, ultra-high voltage construction speed is low and transmission channel construction is imperfect

Rich wind resources of Inner Mongolia are distributed in remote regions which are far away from load center, so large scale wind exploitation must be via by transmission delivery channel of long distance and large capacity blending in local major grid network and bulk power network in other areas [30]. But now the construction of wind power delivery channels of long distance and high voltage classes still lags behind, also, frame of 500 kV transmission line and rural power grid is unsubstantial.

During the 12th Five-Year period, namely from year 2010 to 2015, the $2.28\times10^4$ MW wind power generation of Inner Mongolia grid will be transmission by seven 500 kV alternating current line, a $\pm$660 kV direct current line and a $\pm$800 kV direct line Wind power transmission line route of Mengxi grid can be seen in Table 2 and route map is shown in Fig. 4 [31].

Now Mengxi grid has formed “two horizontal three vertical” structure of 500 kV main power grid network and power supply area of cities in Inner Mongolia has shaped 220 kV main grid network structure. By the end of 2011, network structure of Mengxi grid is shown in Table 2. Two 500 kV “net to net” electric power transmission lines from east to north China have transport capacity of 4300 MW. Power plants with capacity over 6 MW are more than 183 managed by power grid enterprise having a total installed capacity of 42,554.6 MW. There are 85 wind farms in Mengxi with installed capacity up to 8354.7 MW, ranking first in provincial grid company of the nation. The maximum power generation load is 23,209 MW and the biggest power supply load is 18,800 MW including the highest power supply load 15,570 MW in Inner Mongolia region and the highest load delivered from east to north China power grid 4250 MW [32].

MengDong has not yet to form a unified power grid. MengDong grid linked together with Heilongjiang power grid by a 500 kV double circuit line from YiMin plant to FengTun substation, connected to JiLin grid by a 220 kV three circuit line (BaoLongShan–ChangLing, TongLiao–ShuangLiao, TongLiao–JuFeng), and joint to LiaoNing grid with a 500 kV four circuit line and a 220 kV single circuit line. In addition, the transmission channel from MengXi to TuQuan has been abolished. MengDong grid is a typical generation delivery grid because their own installed capacity are far more than load can be digested in local area, large amount of power production need to be deliver to LiaoNing province [33]. In 2011, MengDong grid completed $6.42\times10^7$ MW electricity sales, and year-on-year rate of growth was 24.48%.

“Ultra-high voltage (UHV) UHV” refers to voltage level in which AC over 1000 kV and DC above $\pm$800 kV, with conveying distance more than 2000 km. According to the national power grid planning, UHV construction in Inner Mongolia has two lines, one is 1000 kV ac circuit from Ximeng to Nanjing, and the other is Mengxi to Changsha transmission line [34]. But at the moment only one UHV line is under construction, that is “Ximeng–Shanghai west” 1000 kV AC UHV power transmission and transformation project which can solve the “coal delivered from the air” problem in Inner Mongolia. Nevertheless, construction schedule of UHV only planned limited lines, which is far behind required delivery ability. To build UHV transmission lines need a lot of capital but it still has plenty realistic question to introduce private capital.

The main reason why Inner Mongolia's UHV constructed slowly is government's delay on examining and approval. UHV AC line is always being in controversy and it must be a long time before applying more widely. In 2011, government slowed down the speed of UHV's approval for the government wanted to test operation situation of the sole UHV AC transmission line whose line capacity had just been enlarged. If the maximum delivery ability advanced and risks decreased, other projects could be started then. Approval process of UHV in China relate to many sectors. First, State Grid Corporation of China should report to the National Development and Reform Commission (NDRC), and then conduct water resources argumentation after getting NDRC's qualification. Second, the water conservancy department submits environmental impact assessment report to Ministry of Environmental Protection [35]. Then, after evaluation in prior period, a final approval result of the development scheme will made by the state. In 2012, UHV construction in Inner Mongolia focus on

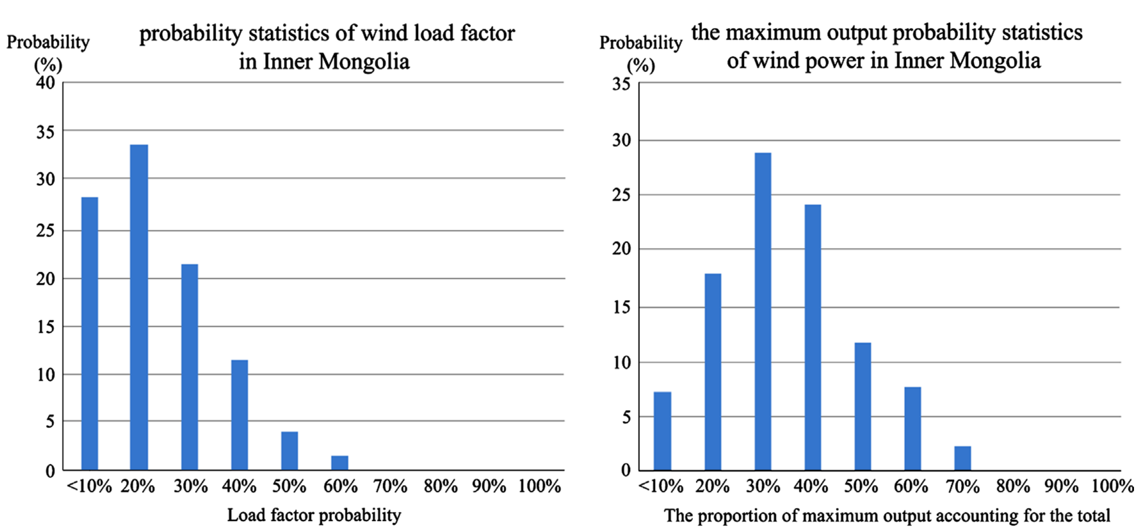


**Fig. 5.** Probability Statistics data of Inner Mongolia grid [28].

matching up approval requirements and completing prophase project evaluation of UHV AC project between Ximeng and Nanjing and between Mengxi and Changsha.

#### 3.1.4. Low load factor affect economics and system operation security

According to wind load data analysis (see Fig. 5), probability of wind power maximum daily loads accounting for 20–50% of installed capacity is 82.76% and probability of maximum daily loads accounting for over 50% of capacity is 10.25%. Besides, due to wind field of Inner Mongolia grid distributed in a wide range, Simultaneity is not enough. Bayannur and Xilingol exist wind power restriction situation effected by grid frame structure so the phenomenon of wind load over 70% of capacity is rare occurrence [28].

Wind load in a low level and electricity power output process curve a steep saw tooth shape. With ultrahigh voltage and UHV transmission lines conveying wind power alone, cause undesirable economics because only around 2000 h are available. To improve transmission load factor and stability, coal-fired thermal stations can act as a power adjustment and supplement measure, at this moment thermal power units will fill a vacant position which means following in reverse as wind power changes and cooperating with wind power to a large extent, otherwise a lot of wind power will waste. So supercritical and ultra-supercritical parameter coal-fired generator units will inevitably break away from optimum condition constantly, adding coal consumption. In addition, whether the measure can satisfy a long-term, frequent and random output operation mode on safety is not sure.

### 3.2. Mechanism obstacle

#### 3.2.1. Two grid subjects is hard to coordinate benefits

There are two grid corporation in Inner Mongolia area, west Inner Mongolia power grid corporation (MengXi) which is belong to local government and east Inner Mongolia power grid corporation (MengDong) which is belong to State Grid Corporation of China. Double subject of power grid cause lack of coordination in network frame construction and transmission.

In June 2009, the whole MengDong grid originally affiliating to Inner Mongolia power grid corporation is transferred to State Grid Corporation of China for unified operation. Inner Mongolia power grid company is produced after the reform of “plant separating from grid” as one of three power grid companies in China, and also as the only independent provincial power grid enterprise, but all rights and interests of transmission channel's construction such as establishment, construction, management, maintenance and supervision right, basically mastered by state grid.

During the 11th Five-Year Plan period, Inner Mongolia electric power installed capacity added faster than electricity load, newly installed capacity for 21,000 MW with average annual growth of 25%. But because of the third and fourth delivery channel of MengXi grid did not carry out as planned, cause capacity in MengXi grid surplus [36]. If MengXi electricity generation want to deliver outside, it must pass-through the only large delivery channel, the north China power grid of State Grid Corporation of China. And how much electricity MengXi grid transmitted is decided by the purchaser the north China power grid. Transmission Generation from MengXi grid to the north China power grid at night cannot reach the level of the day, if 4000 MW generation (3900 MW in the day)accepted after midnight (from 23:00 to 7:00) will cause units in Beijing–Tianjin–Hebei grid closing down in the night and decommissioning units cannot start in time second day which leads to power demand on peak time cannot meet and makes economic benefit of power generation enterprises under administration of State Grid Corporation of China-declined [37]. On the situation that wind power and thermal power sharing limited delivery channel, wind power with feature of intermittency and volatility has no delivery priority. Thermal power delivered first further intensifies the problem of grid-connected wind power in low rate. Interregional power delivery faces interest coordination and compensation problems between regions.

#### 3.2.2. Imperfection price and subsidy mechanism

In order to increase wind generator output, the only method now is cutting thermal power unit output, and thermal power load shifting compensation mechanism is yet not to be established, so thermal power cannot share benefits with wind power. Lacking of market incentive mechanism, thermal power unit conducting load shifting for wind power unit only can be achieved through the administrative order in force, and it is not a sustainable development measure [38]. On the current situation, the wind power taxes are heavy and loan interest is too high. At present China's value-added tax rate is generally 17%, but wind power enjoy 8.5% discount. For example, the Inner Mongolia power company sales income is 46.11 billion yuan in 2011, and it can bring 3.92 billion

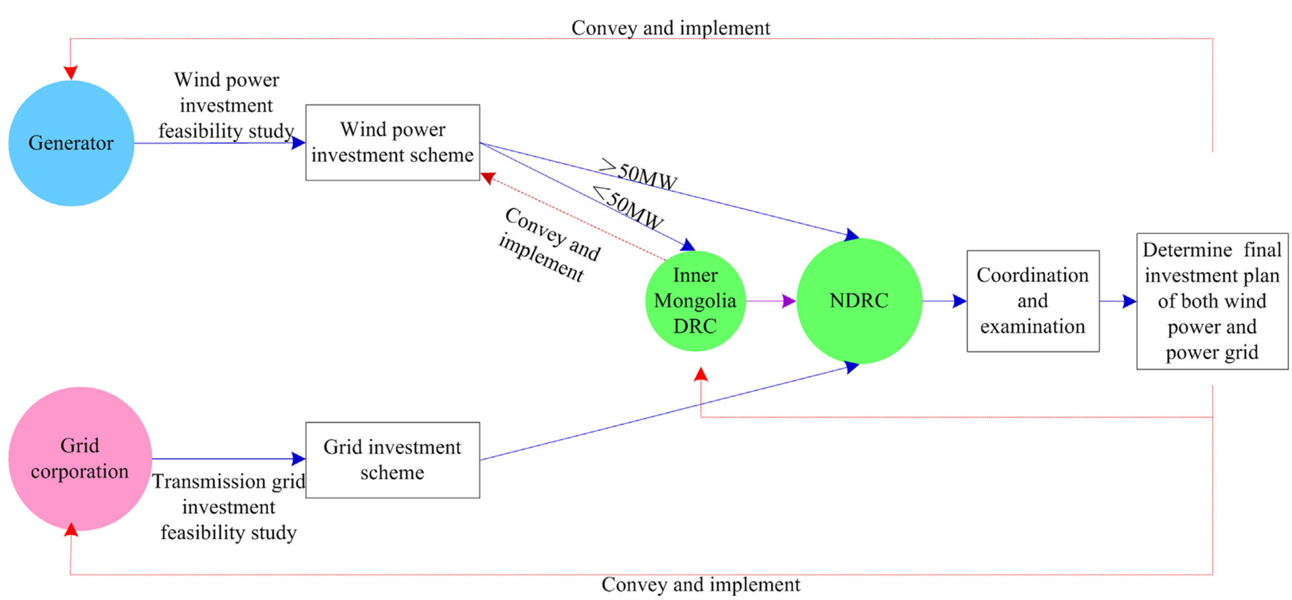


**Fig. 6.** Wind power and power grid coordinated planning flow chart in Inner Mongolia region.

dollars value added tax income to Inner Mongolia local finance. However, wind power is not like coal which has a fuel input tax deduction. Actually wind power taxes are higher than coal taxes, thus cause a high grid-access price of wind power impacting power grid's enthusiasm to accept wind power.

## 4. Solutions

### 4.1. Technical aspect

#### 4.1.1. Coordinate wind power and grid planning

Grid corporation and power generation enterprise, as independent investment subject, respectively formulate investment plan and report to NDRC. Therefore, in the process of wind power and power grid planning, the government should play an active coordination function, as shown in Fig. 6.

Power suppliers and power grid companies respectively determine wind power investment scheme and grid investment plan through feasibility study of the project, and then report to development and reform commission for agreement and instruction. For wind power investment plan with installed capacity more than 50 MW directly report to the NDRC and for less than 50 MW report to the Inner Mongolia autonomous region development and reform commission. In order to solve the prominent problem of "49.5 MW" wind power investment, wind power investment plan less than 50 MW which has approved by Inner Mongolia development and reform commission must be timely reported to the NDRC. The NDRC makes a comprehensive consideration of passing 50 MW wind power investment plan that approved by autonomous region development and reform commission, capacity more than 50 MW investment scheme and power grid investment program. In addition, the NDRC also need to put wind power and power grid investment plan into consideration as a whole, determining the optimal investment scale and planning to improve investment efficiency, and feedback the final approved plan to investors. If any market player have objections to the final scheme, can apply to NDRC for reconsideration. This proposed scheme has not been done, but it is a suggestion.

#### 4.1.2. Increase wind power integration supporting power sources

*4.1.2.1. Promote construction of wind power integration supporting power sources.* In the calm circumstances, in order to ensure the normal use of energy instead of wind power is needed. So, in the construction of wind farms, the related mating wind power integration supporting power sources are also need to develop at the same time, such as power plant or hydropower station, etc. But it does not mean the supporting power sources must be built near wind farms, it can build within the scope of grid cover. Places like Inner Mongolia region without abundant water resources can build pumped storage power station to promote wind power integration [39]. Meanwhile, encouraging more thermal power units to participant in load shifting of wind power integration are required. The specific incentive measures will be analyzed next in mechanism level.

*4.1.2.2. Promote self-provided power plant for load regulation.* Currently self-provided power plant capacity in Inner Mongolia power grid is 2450 MW. According to the principle of spontaneous private, these power plants neither participate in power grid peak shaving, nor to provide spare capacity for grid, which is unfavorable to wind power's normal operation. Self-provided power plants approved by the nation are basically cogeneration units. In order to ensure the normal operation of wind power, self-provided power plants transfer to public auxiliary plants participating in load shaving should be encouraged. We suggest that collect 0.05 yuan/kW h of generation produced by self-provided plants as capacity fee of renewable energy load adjustment. At the same time establishing relevant policy strictly control the construction of self-provided power plants.

#### 4.1.3. Strengthen grid construction

Inner Mongolia autonomous region is one of the most rapidly electric power industry developing areas in China during "11th five-year plan" period. With the sharp increase of generating capacity, power output "obstruction" become significant problems when implement power transmission from west to east or from north to south [36]. According to the successful practice of Inner Mongolia power grid, consumption rate of wind power is above 10% in average, and over 20% for more than a month and more than 30% for days. Wind power has become one of the main power supply without doubt. Inner Mongolia should speed up the power delivery channel construction, and upgrade or perfect 500 kV main grid frame structure and rural grid structure, and promote ultrahigh voltage or UHV grid approval efficiency and construction speed, at last vigorously improve delivery ability of clean energy.

*4.1.3.1. Upgrade grid structure and accelerate the construction of power transmission delivery channel.* Wind generation have been close to 10% of total integration generation in Inner Mongolia during the 11th Five-Year Plan period, and only if wind power continues to increase in a high speed in 12th Five-Year Plan period the condition the state required of wind digestion across provinces can be realized. The suggestions of development plan in 12th Five-Year Plan period is: first, develop a new ultrahigh voltage transmission channel from MengXi power grid to the Beijing–Tianjin–Hebei region; Second, construct UHV DC channels between Ordos and central China and between South Huhhot and Nanchang, and the two channels connected to Mengxi grid; Then, wind power in Northern regions and thermal power in coal supply bases are collected to UHV DC channels by MengXi power grid 500 kV main network structure.

In MengDong district, a 500 kV substation should be approved and constructed in Hinggan League Ulanhot, and double circuit 500 kV lines of Ulanhot–Horqin, Ulanhot–Baicheng, and Ulanhot–Qinan need to be constructed as supporting; In TongLiao district two 500 kV substations respectively developed in KaiLu and Zhurihe and supporting projects including double 500 kV lines from Kailu–Horqin, Zhurihe–Horqin, and Horqin to Xinmin; In Chifeng area, a 500 kV substation in Chifeng, and double circuit 500 kV lines of Chifeng–Balin, Chifeng–Qingshan and Balin–Fuxin should be constructed; at last, in Hulun Buir district further speed up carrying out the $\pm 800$ HVDC project construction between Bayantuohai and shandong.

*4.1.3.2. Strength organization leadership.* According to the principle of dependency administration, set up coordination institution for grid construction projects in charge of government leaders who are responsible for the institution. For grid construction projects in subordinate region, the institution should organize regular meeting to coordinate planning and construction related matters. Take power grid planning into consideration of the region development planning system, and realize synchronous connection between power grid development planning and other planning. Local governments at all levels and the relevant departments in Inner Mongolia should strengthen information communication with power sector, coordinating and solving specific problems in grid construction.

*4.1.3.3. Form scale effect of small scale wind farms.* Some small scale wind farms are in remote areas where power grid enterprises lose incentives to invest grid construction. But multi-wind farms in

remote areas can form scale effect to push grid construction investment. At the same time, enhance wind power development access conditions and greatly reduce the number of development operation subjects. In addition, solve problems such as dispersion of wind power development subjects, influence to group operation efficiency and energy waste.

### 4.1.4. Others

*4.1.4.1. Promote high energy-consuming enterprises in Inner Mongolia to consume local wind power nearby*. Building high energy-consuming projects near wind farms, and in the meantime, promoting wind power directly combined with high load industry from the policy. For example, The China Power Investment Corporation conducts micro network operation based on coal, electricity, aluminum industrial park in MengDong HuoLinHe district, the result is 30% of local wind and photovoltaic generating electricity digested. Iron and steel, nonferrous metal, building materials and chemical industry as four high energy-consumption industry occupy the whole society power consumption by more than 30%, therefore, if more high power consumption enterprises are introduced into the wind power surplus areas, not only can solve the limitation channel and transmission line cost problems, but also improve utilization efficiency because of wind power generation digestion in local.

*4.1.4.2. Develop decentralized and distributed wind power.* Vigorously develop distributed wind power with characteristic of small scale, low voltage, nearly digestion and directly access to distribution network system. To develop large-scale and centralized wind power can study actively first, and waiting for an optimum time or opportunity to full implementation. In July 2012, the government issued the “notice about development of distributed access wind power” and in the end of the year issued “instruction opinion about development and construction of distributed access wind power projects”. The file defines strictly for definition of distributed access wind power project, access voltage level, project scale, examination and approval process and so on, clearly showing the attitude that the state encourages distributed wind power's development. Even though distributed wind power is still in experimental stage so far, its outstanding adaptability and cost performance decide that it will have a bright development prospects.

Distributed small and medium-sized wind power can connect to grid and utilize nearby because of small generated electricity, and long distance transmission is not required. Especially in the power load center areas, if small scale wind farms constructed near to users, power pressure can relieve, so this kind of wind power will not exist digestion difficulties.

For a long time, high cost and low profit is the main factor to limit China's small and medium-sized wind power development [40]. In recent years, wind farm procure domestic fan to cut costs, making a certain profit space to China's distributed wind power. The State Grid Corporation of China is promoting trial work on intelligent distribution network, which also provides access conditions for distributed energy.

Therefore, national policy and intelligent power system technology support provide favorable conditions for the development of small scale distributed wind power.

## 4.2. Mechanism

### 4.2.1. Coordinate benefit between local grid and state grid

In 2011, the maximum power gap in eastern and central region reached for 30 GW, but Mengxi grid was 10 GW surplus this year. The State Grid Corporation and regional power grid company do not reach an agreement on interest distribution, leading to face multiple resistance of interprovincial power channel construction.

*4.2.1.1. Establish a regular meeting system and strengthen cooperation communication.* Adopting a third party institution such as an organization managed by the department of energy, or establishing a special department with members from both benefits sides. The purposes of building this department are to set up a regular meeting system, and strengthen communication between the national power grid and Mengxi grid reaching an agreement on scientific development and forming sustainable development planning. At present, as for the particularity of the power grid enterprise management, to establish a cooperation alliance in power supply area, taking power grid planning, construction, operation and scheduling into consideration from the whole Inner Mongolia region is a reasonable solution to solve interest conflict between provincial and local power grid companies. Through the regular meeting system, the interests of both parties are considered, and the idea of a win–win situation set up.

*4.2.1.2. Build a joint venture company*. The best way to solve conflicts between provincial and local power grid company is to set up a joint ventures in the area invested by all related parties, realizing a unity management of grid planning, construction and operation. The local government must give a certain degree of support to the new company and reduce some burdens of the new company, such as preferential policies on land requisition for construction, remove compensation, taxes, surplus staff arrangement, all of which are good to improve the benefit of the new company. In the adjustment of price for power supply area, as far as possible adjust in place year after year according to the new company's profitability. Because of the price adjustment related to the parties, and has a significant influence on the new company's cash flow, it is the key factor to a successful cooperation relationship. We suggest that in cross power supply area of the provincial and local grid to implement the national electricity price policy according to the relevant state policies and actual situation in the area.

### 4.2.2. Improve price mechanism and subsidy policy

*4.2.2.1. Improve price mechanism.* Establish a interests compensation mechanism for wind load shifting or a trading platform for grid peak shaving with thermal power, pumped storage power station and others as the subject of load adjustment Through the effective compensation and incentive mechanism, solve economic loss for thermal power in the process of peak shaving for wind power, improving the enthusiasm of all parties to accept wind power.

At present, China is making great efforts on energy saving and emission reduction. Power grid enterprises need to consider both economic benefits and social responsibility. The trend of enlarge the proportion of clean energy such as wind power is certain, but wind power grid-connected involves many benefit gambling problems, and ultimately integration wind power generation is changeable. And for effectively use, Inner Mongolia wind power must be digestion in a large area outside the Inner Mongolia region, while power grid load shaving/standby trading platform will consider problems like the optimal benefits, the optimal coal consumption, environmental problems and cost minimum in cross area trading. Introduction of market transactions in peak shaving market and conducting paid transaction for peak shaving load among power plants, can effectively reduce system cost of load shifting and optimize the structure of the units, and at the same time provide s a way to trade for units participated in the auction market. Besides, spare load shifting units guarantee security of power grid.

In addition, for the wind load regulation units implement capacity price mechanism while wind generator units carry out electricity price mechanism is a possible solution to the interest compensation issues between load regulation resources given priority to wind power and thermal power. In this kind of price

mechanism, wind power and thermal power is no longer competitive relationship but complementary relationship. It cannot only arouse the enthusiasm of thermal power unit to load shifting, but also can promote the positivity of wind power integration.

*4.2.2.2. Improve subsidy policy*. If public thermal power units undertake all responsibility for peak shaving, service hours will restricted by about 30% impacting economic benefits. The relevant departments should make sure subjects of peak shaving (self-provided power plant, gas units, pumped storage power station) and corresponding compensation standard as soon as possible. As for specific policy about promoting renewable energy power integration, only exist an investment subsidies policy made by the national development and reform commission at present. The policy issued in early 2007 and was specifically formulated for transmission lines constructed in renewable energy power generation projects providing 1–3 cents/kW h allowance for grid-connected [41]. The Renewable Energy Law stipulates that power grid must purchase full renewable energy power integration generation for indemnificatory, but in the process of implementation face the problem of how to determine the minimum annual quota index. To economic compensation and incentive problems getting from technology difficulties of renewable energy such as accepting wind power in grid, specific policy has not drafted. At the same time, government should issue wind power dispatch standard and regulatory measures as quickly as possible, and reduce the phenomenon of wind power grid-connected restricted by artificial limits. In a word, the current renewable energy power generation integration policy mainly pays attention to mandatory requirement that power grid enterprises purchase all renewable energy power electricity, but lack of policies and measures to meet the requirement of security and stable operation of the grid.

The current compensation standard only consider the recovery of grid line investment which is for grid-connected of new renewable energy (like wind) power generation projects. In other words, the compensation only take the investment that wind power stations connected to main network backbone of power grid, but regardless of ultrahigh voltage and UHV lines' investment recovery and other units' peak shaving compensation.

## 5. Conclusion

At the end of 2011, the cumulative wind power installed capacity in Inner Mongolia accounts for 28.21% of wind capacity in China, while its annual output occupied only 27.42% of that in China. Wind power development in Inner Mongolia are severely restricted by technical and mechanical problems such as imperfect delivery channel construction, insufficient peak-shaving capacity and imperfect subsidy policies. To speed up and guarantee the secure and economic development in Inner Mongolia in strategic height of energy structure and safety, can greatly improve the ratio of green power in China.

On technical level, first, plan the construction of mating pumped storage power station and other energy storage projects with mature technical, which can improve the stability of large-scale wind power's transmission. and give full play to self-provided power plant's ability for load shifting as well; Second, to the phenomenon that wind power and power grid planning uncoordinated, mainly depend on wind power investors, grid companies and government this three parties to solve; Third, strengthen to upgrade and improve 500 kV main grid frame structure; Fourth, it is suggested that government start construction of long distance UHV transmission project as soon as possible as issued in 12th Five-Year planning. At the same time, increase transmission channel construction projects connected between high voltage line and grid in adjacent area; at last but not the least, wind power digestion in local and develop small-scale and distributed wind power as much as possible are all solutions to developing predicament of Inner Mongolia wind power. On mechanical level, cooperating the interests of all parties, establishing electric trading platform for peak shaving and perfecting interest compensation mechanism of load shifting subjects in the market are the key to the future development of wind power in Inner Mongolia.

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